# E-CLOUD BUILD-UP IN GROOVED CHAMBERS*

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*Abstract*

We simulate electron cloud build-up in a grooved vacuum chamber including the effect of space charge from the electrons. We identify conditions for e-cloud suppression and make contact with previous estimates of an effective secondary electron yield for grooved surfaces.

## SUMMARY OF WORK

Corrugating the interior of a vacuum chamber with small grooves is one of the possible remedies currently investigated for suppressing the electron cloud accumulation in storage rings. Analytical and numerical modelling of the interaction of electrons with grooved surfaces have indicated the effectiveness of this technique and accelerator-based experiments to confirm these results are planned or already underway. Previous simulations [1, 2, 3] so far have generally aimed at determining an effective secondary electron yield (SEY) by considering a beam of monochromatic electrons (primary particles) impinging on the grooved surface and keeping track of the electrons (secondary particles) emerging from the groove regions – a setting typical of laboratory bench measurements where an effective SEY can easily be determined as a function of the energy of the primary electron beam. In the work described here we are interested in a direct characterization of the electron cloud build-up in the vacuum chamber of an operating accelerator in the presence of both the driving beam and space-charge from the electrons. This will be useful for a closer comparison between current e-cloud modelling and accelerator-based measurements.

We carried out our work by augmenting the current version of the code POSINST to include the option to follow the electron dynamics in the presence of grooves. Electron-surface collisions and secondary electron production following those collisions are modelled using the modules already built in POSINST [4]. At present we have a provision to simulate rectangular cross-section vacuum chambers with triangular grooves located on the top and bottom sides – closely reproducing the configuration a proposed e-cloud experiment at PEP-II. The steepness angle $\alpha$ of the triangular grooves as well their height (see Fig. 1) are input parameters controlled by the user. An option to include rounding of the groove tips has also been implemented. Space charge from the electrons is included in the model. However, at present the electric field lines are terminated on a hypothetical smooth surface immediately behind the grooves thus neglecting possible field enhancement by the groove tips.

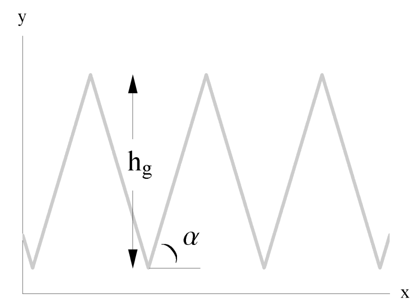


Figure 1: Triangular grooves (with sharp tips) are characterized by steepness angle $\alpha$ and height $h_g$.

We illustrate POSINST new features by showing an application to the ILC positron damping ring (DR), for which electron cloud is a very serious concern. There is wide consensus that the current baseline specifications for the ILC DRs can only be achieved if effective e-cloud suppression techniques can be developed beyond levels currently demonstrated. Failure of doing so could result in substantial increase in cost (*e.g.* the installation of an additional damping ring) or degradation of the collider performance [5].

Grooves reduce the effective SEY by increasing the probability that immediately after production secondary electrons may be rapidly reabsorbed through wall collisions and therefore prevented from contributing to multipacting. The effectiveness of the grooves strongly depends on the geometry. For triangular grooves the existence of a critical angle for effective suppression of the electron cloud can be clearly extracted from Fig. 2. The picture shows the maximum linear electron density accumulated during the single passage of a 111-positron bunch train through one of the ILC DR dipoles as a function of the triangular grooves steepness angle $\alpha$. The bunch train is $0.68$ $\mu$s long, for a $6.1$ ns separation between bunches. The bunches have a population of $2 \times 10^{10}$ and sizes $\sigma_x = 0.62$ mm, $\sigma_y = 8$ $\mu$m, $\sigma_z = 6$ mm (this is smaller than the current baseline value $\sigma_z = 9$ mm). The magnetic field in the

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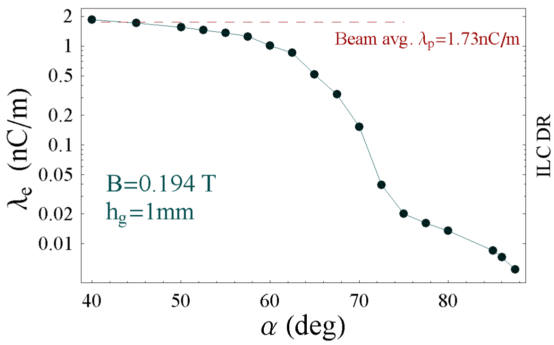


Figure 2: Maximum linear density of electrons accumulated during a passage of a train of positron bunches in a ILC damping ring dipole *vs.* steepness angle $\alpha$ of triangular grooves (with sharp edges). Al chamber with $\delta_{\max} = 1.75$.

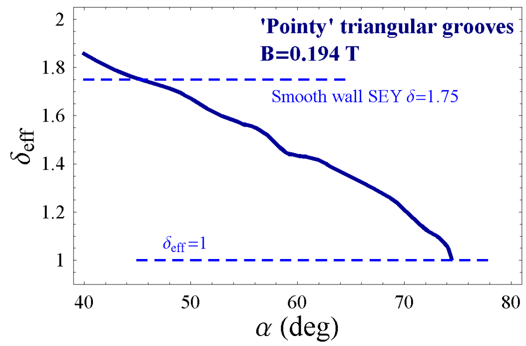


Figure 3: Effective SEY as a function of the steepness angle $\alpha$ as derived from the simulation of e-cloud build-up.

dipoles is about 0.2 T. The calculation is for grooves height $h_g = 1$ mm and the model of SEY adopted was that of Al, with maximum SEY set to $\delta_{\max} = 1.75$.

A drop in electron density by about two orders of magnitude compared to the smooth-chamber case is seen to occur for steepness angle $\alpha$ larger than $75°$. For shallower angles the electron accumulation is increasingly larger, approaching and in fact slightly overtaking the electron cloud density for a smooth surface when $\alpha < 45°$. This latter behavior is not implausible. It is a basic property of the model employed in the calculation that the SEY is minimum for electrons hitting the surface at a normal incidence. At a smaller $\alpha$ the grooves become ineffective at capturing the secondaries and the effective SEY may become larger if on average the primary electrons hit the surface off the local normal.

To make contact with previous studies we extracted an effective max SEY from our data by making comparison with the electron density we would obtain in a smooth chamber as we vary the value of $\delta_{\max}$ for the smooth surface. An effective yield corresponding to a given $\alpha$ is then defined as that $\delta_{\max}$ producing the same maximum e-cloud accumulation in a smooth chamber during the passage of the same train of positron bunches. The result is shown in Fig. 3 where the effective max. SEY is plotted as a function of the steepness angle $\alpha$. The curve is reasonably smooth and again indicates $\alpha \simeq 75^o$ as the critical angle where the effective secondary yield crosses into values smaller than unity corresponding to effective electron cloud suppression.

Our results are substantially consistent with calculations reported in [1], where for the same groove geometry (and same maximum SEY for the smooth surfaces) an effective secondary yield as a function of energy is found to remain <1 for angles just above $\alpha \simeq 70°$. Both the present and Wang *et al.*'s findings are somewhat less pessimistic than those obtained by W. Bruns [3], which indicate that an angle $\alpha = 75°$ would still yield an effective SEY larger than unity; $\alpha = 75°$ was the largest steepness angle reported in [3] but a rough extrapolation from the data shown would appear to predict a noticeably larger critical angle for a SEY<1.

During discussions at the workshop it was mentioned that these discrepancies in the results could perhaps be ascribed to differences in the SEY model at low electron energies. While in the model used by W. Bruns $\delta(E)$ is unity at zero energy [6, 7] (and displays a local minimum at low energy ) in the POSINST model (and possibly in L. Wang's calculations [1]), the same limit is $\delta(0) \simeq 0.5$ [4]. It is not unlikely that the capturing properties of the grooves may be sensitive to the details of the yield curve at small energy but we have yet to run simulations to test this supposition.

In further calculations we studied the dependence of the e-cloud suppression properties on groove height and rounding of the groove tips. The latter would be a desirable feature for taming the impact on the beam impedance caused by the grooves and to ease manufacturing tolerances. We found that rounding the tips could significantly decrease the efficacy of the grooves and should therefore be included in the modelling. More details will be reported elsewhere.

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